In re Patent Application of: Tetsuo Fujii et al.

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For: SEMICONDUCTOR MECHANICAL SENSOR





TRANSLATOR'S DECLARATION

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Washington, D.C. 20231

Sir:

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(1) That I know well both the Japanese and English languages;

(2) That I translated Japanese Patent Application No. 4-273202, filed October 12, 1992, from the Japanese language to the English language;

(3) That the attached English translation is a true and correct translation of the aforesaid Japanese Patent Application No. 4-273202 to the best of my knowledge and belief; and

(4) That all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements are made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001, and that such false statements may jeopardize the validity of the application or any patent issuing thereon.

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| [TITLE OF THE INVENTION] | SEMICONDUCTOR MECHANICAL SENSOR AND METHOD OF MANUFACTURE THEREOF |
| [NUMBER OF CLAIMS] | 4 |
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| [Name of Article] | Specification 1 |
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| [Name of Article] | Abstract 1 |
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[NEED FOR PROOF] Yes

[DOCUMENT NAME] SPECIFICATION

[TITLE OF INVENTION] Semiconductor Mechanical Sensor and Method of Manufacture Thereof

[SCOPE OF CLAIM FOR PATENT]

[CLAIM 1] A semiconductor mechanical sensor, characterized in that it comprises:

a thin monocrystalline silicon substrate which is joined onto a substrate through an insulation film;

a beam which is formed on said monocrystalline silicon substrate, said beam having a weight;

first electrodes which are formed in one surface of said weight and a wall surface which corresponds to the weight surface; and

second electrodes which are formed in one surface of said weight and a wall surface which faces the weight surface in an axial direction which is perpendicular to said first electrodes of said weight.

[CLAIM 2] A semiconductor mechanical sensor in accordance with claim 1, wherein either one of said electrodes is formed on a major surface of a monocrystalline silicon substrate in parallel therewith.

[CLAIM 3] A semiconductor mechanical sensor in accordance with claim 1, wherein all electrode contacting portions are formed on the same surface of said thin monocrystalline silicon substrate.

[CLAIM 4] A method of manufacturing a semiconductor mechanical sensor, characterized in that it comprises:

a first step of forming a groove of a predetermined depth in a major surface of a monocrystalline silicon substrate to thereby form a beam which has a weight;

a second step of forming a pair of electrodes which face each other on the opposite sides of the groove in the direction of a surface of the substrate in a region of the surface of the substrate which serves as said weight and in an inner wall of the groove which surrounds the

weight, and of forming a first electrode in a direction which is perpendicular to the surface of the substrate in the region of the surface of the substrate which serves as said weight;

a third step of filling said groove with a filling material, forming an electrode so that the electrode and said first electrode face each other on the opposite sides of the filling material, and of smoothing the major surface of said monocrystalline silicon substrate;

a fourth step of joining the major surface of said monocrystalline silicon substrate to the substrate;

a fifth step of polishing a back surface of said monocrystalline silicon substrate by a predetermined amount to thereby make the monocrystalline silicon substrate thin; and

a sixth step of etching said filling material from the back surface side of said monocrystalline silicon substrate to thereby form the beam which has the weight.

[DETAILED DESCRIPTION OF INVENTION]

[0001]

[Field of Utilization in Industry]

The present invention relates to a semiconductor mechanical sensor and method of manufacturing the same, and more particularly, preferably to a yaw rate sensor and a method of manufacturing the same.

[0002]

[Prior Art]

The applicant of this application has proposed a semiconductor yaw rate sensor in the Japanese patent application number HEI 4-223072. The semiconductor yaw rate sensor is so configured, as shown in Fig. 17, that a beam structure is formed as one portion of a semiconductor substrate spaced from other portions of the substrate, that an AC power is applied to one surface of a weight formed at the tip of the beam and to the wall surface of the substrate

facing the weight surface, thereby to oscillate the weight by static electricity, and that a pair of electrodes facing each other are provided on one surface of the weight and the wall surface of the substrate facing the weight surface in the axial direction perpendicular to the direction for oscillating the weight, to detect a change in electrical capacitance between the pair of electrodes facing each other, thereby detecting a yaw rate which acts in the same direction.

[0003]

[Problems to be Solved by the Invention]

However, in a semiconductor mechanical sensor which moves in two directions as in the semiconductor yaw rate sensor, specific structure has not been well clarified and manufacturing method thereof has not been touched on at all, and these have been problems to be solved.

[0004]

An object of the present invention is to offer a yaw rate sensor using a beam oscillation type capacitance detection system and a method of manufacturing the same, and to offer a semiconductor mechanical sensor which can detect movement conditions in two or three directions (when two such semiconductor mechanical sensors are used) and a method of manufacturing the same.

[0005]

[Means for Solving the Problems]

The first invention is a semiconductor mechanical sensor comprising a thin monocrystalline silicon substrate which is joined onto a substrate through a insulation film; a beam which is formed on the monocrystalline silicon substrate, the beam having a weight; first electrodes which are formed in one surface of the weight and a wall surface which corresponds to the weight surface; and second electrodes which are formed in one surface of the weight and a wall surface which faces the weight surface in an axial direction which is perpendicular to the first electrodes of the weight.

[0006]

Also, it is preferable that either one of the electrodes facing each other is formed in parallel with each other on a major surface of the monocrystalline silicon substrate.

Further, it is preferable that all electrode contacting portions are formed on the same surface of the thin monocrystalline silicon substrate.

[0007]

The second invention is a method of manufacturing such a semiconductor mechanical sensor comprising the steps of:

a first step of forming a groove of a predetermined depth in a major surface of a monocrystalline silicon substrate to thereby form a beam which has a weight;

a second step of forming a pair of electrodes which face each other on the opposite sides of the groove in the direction of a surface of the substrate in a region of the surface of the substrate which serves as the weight and in an inner wall of the groove which surrounds the weight, and of forming a first electrode in a direction which is perpendicular to the surface of the substrate in the region of the surface of the substrate which serves as the weight;

a third step of filling the groove with a filling material, forming an electrode so that the electrode and the first electrode face each other on the opposite sides of the filling material, and of smoothing the major surface of the monocrystalline silicon substrate;

a fourth step of joining the major surface of the monocrystalline silicon substrate to the substrate;

a fifth step of polishing a back surface of the monocrystalline silicon substrate by a predetermined amount to thereby make the monocrystalline silicon substrate thin; and

a sixth step of etching the filling material from the back surface side of the monocrystalline silicon substrate to thereby form the beam which has the weight.

[0008]

[Mode of Operation]

According to the first invention, a mechanical force

applied to the beam having the weight is detected by the first electrodes and the second electrodes in an axial direction perpendicular to said first electrodes.

[0009]

According to the second invention, in a first step, a groove of a predetermined depth is formed on a major surface of a monocrystalline silicon substrate to thereby form a beam having a weight. Then, in a second step, a pair of electrodes facing each other are formed on the opposite sides of the groove in the direction of a surface of the substrate in a region of the surface of the substrate which serves as the weight and in an inner wall of the groove which surrounds the weight, and a first electrode is formed in a direction which is perpendicular to the surface of the substrate in the region of the surface of the substrate which serves as the weight. Further, in a third step, the groove is filled with a filling material, an electrode is formed so that the electrode and the first electrode face each other on the opposite sides of the filling material, and the major surface of the monocrystalline silicon substrate is smoothed. Next in a forth step, the major surface of the monocrystalline silicon substrate and a silicon substrate are joined, and in a fifth step, a back surface of the monocrystalline silicon substrate is polished by a predetermined amount to thereby make the monocrystalline silicon substrate thin. Finally, in a sixth step, the filling material is removed by etching from the back surface side of the monocrystalline silicon substrate to thereby form the beam having the weight. As a result, the semiconductor mechanical sensor according to the first invention can be manufactured.

[0010]

[Embodiments]

(First Embodiment)

One embodiment which embodies this invention is described below with reference to the accompanying drawings.

[0011]

Fig. 2 is a schematic plan view of the semiconductor yaw

rate sensor according to the present embodiment. That is, in the illustrated sensor, a cantilever 102 is formed in a monocrystalline silicon substrate 101 so as to include a weight 139 at the tip. In a tip portion of the weight 139, three projections 103, 104 and 105 are formed spaced from each other to extend along the elongation of the beam. On the monocrystalline silicon substrate 1 side facing the tip portion surface of the cantilever 102 (weight 139), between the projections 103 and 104, two projections 106 and 107 are formed spaced from each other to extend in parallel to the projections 103 and 104. In a similar manner, on the monocrystalline silicon substrate 101 side facing the tip portion surface of the cantilever 102 (weight 139), between the projections 104 and 105, two projections 108 and 109 are formed spaced from each other to extend in parallel to the projections 104 and 105.

[0012]

Fig. 3 is a plan view showing the semiconductor yaw rate sensor including the electrodes. Fig. 1 is a view showing a cross section of Fig. 3 taken along the line A-A. In the drawings, an IC circuit, wires and the like formed in an SOI circuit are omitted and external contacting aluminum electrodes alone are shown as an electrode for picking up a capacitance, an oscillation electrode and the like in the sensor. In other words, all electrode contacting portions are formed on the major surface of the monocrystalline silicon substrate 101.

[0013]

As shown in Fig. 1, the monocrystalline silicon substrate 101 is joined to a monocrystalline silicon substrate 110 through an $SiO_2$ film 111. In this monocrystalline silicon substrate 101, the beam structure described earlier is formed.

[0014]

In Figs. 1 and 3, in a surface of the weight 139 of the cantilever 102, a movable electrode 112 is formed. The

movable electrode 112 includes the three projections 103, 104 and 105 of the weight 139. In addition, two electrodes 113 and 114 are formed below the weight 139. The oscillation electrode 114 oscillates the weight 139 by static electricity energized by an AC power. In short, the movable electrode 112 and the oscillation electrode 114 form oscillation electrodes.

[0015]

The sense electrode 113 detects oscillation of the weight 139, and based on the output signal which is generated in response to oscillation of the weight 139, a feedback control is performed to thereby achieve predetermined oscillation of the weight 139. That is, the movable electrode 112 and the sense electrode 113 form electrodes for oscillation feedback.

[0016]

As shown in Fig. 3, on both sides of the projection 103 of the cantilever 102, fixed electrodes 133 and 134 (projection 106) are formed while on both sides of the projection 104, fixed electrodes 135 (projection 107) and 136 (projection 108) are formed. Further, on both sides of the projection 105, fixed electrodes 137 (projection 109) and 138 are formed. In other words, the projection 103 (movable electrode 112) and the fixed electrodes 133 and 134 form electrodes while the projection 104 (movable electrode 112) and the fixed electrodes 135 and 136 form electrodes. In addition, the projection 105 (movable electrode 112) and the fixed electrodes 137 and 138 form electrodes.

[0017]

Figs. 4 to 8 show manufacturing steps. In the following, the manufacturing steps will be described.

As shown in Fig. 4, an n type (100) monocrystalline silicon substrate 101 of 1 to 20 Ω·cm is prepared, and a recess portion 115 is etched in a major surface of the monocrystalline silicon substrate 101 by dry etching or wet etching to a predetermined depth, e.g., 0.1 to 5 μm. An $SiO_2$ film is formed on the major surface of the monocrystalline

silicon substrate 101 and patterned by a photolithographic method. Following this, in the major surface of the monocrystalline silicon substrate 101 including the bottom portion of the recess portion 115, a trench 116 of a depth of about 0.1 to 30 μm is formed by dry etching or other suitable technique.

[0018]

In this embodiment, a groove is formed by the recess portion 115 and the trench 116.

On the major surface of the monocrystalline silicon substrate 101 including an inner wall of the trench 116, an $n^+$ type diffusion layer 117 is formed which will be then covered with an $SiO_2$ film 118 by thermal oxidization.

[0019]

Following this, as shown in Fig. 5, a polysilicon film 119 is buried in the recess portion 115 and the trench 116 by an LPCVD method.

The surface of the polysilicon film 119 is then polished using the $SiO_2$ film 118 as a stopper to smooth the surface of the polysilicon film 119. At this stage, the surfaces of the polysilicon film 119 and the $SiO_2$ film 118 are preferably smoothed.

[0020]

Then, in the surfaces, an $SiO_2$ film 120 is formed to a thickness of about 0.3 to 2 μm by a CVD method or other suitable method, and a bottom contact 121 is formed at a predetermined location for electrical connection with the $n^+$ type diffusion layer 117.

[0021]

Further, an $n^+$ polysilicon 122 doped with As and P (phosphorus) is formed to a thickness of 0.2 to 1 μm which will serve as a predetermined electrode pattern and a shield layer.

Next, a BGSP film 123 which serves as an insulation film, for instance, is formed to a thickness of 0.2 to 1 μm in the

surface. The surface of the BGSP film 123 is then polished and flattened.

[0022]

On the other hand, as shown in Fig. 6, a silicon substrate 110 is prepared and an $SiO_2$ film 111 is grown to a thickness of 0.2 to 1 μm in a surface of the silicon substrate 110 by thermal oxidization.

Following this, as shown in Fig. 7, the silicon substrates 101 and 110 are joined to each other through the $SiO_2$ film 111 within $N_2$ at a temperature of 1000°C, for instance. A back surface of the monocrystalline silicon substrate 101 is then selectively polished using the $SiO_2$ film 118 as a stopper. As a result, the polysilicon 119 and an isolated region of the silicon substrate 101 are exposed to the surface.

[0023]

An IC board and other devices (not shown) are then formed in the region of the monocrystalline silicon substrate 101 by a known method, and aluminum wires, a passivation film and a pad window (these elements are not shown) are formed as well.

[0024]

Next, as shown in Fig. 8, the $SiO_2$ film 118 is removed at a predetermined region, and the polysilicon film 119 is removed at a predetermined region using an etching hole 124 which is shown in Fig. 3. An etching solution may be TMAH (tetramethylammoniumhidroxide), for example. As a result of etching, a movable electrode (beam portion) is formed.

[0025]

In the semiconductor yaw rate sensor fabricated in this manner, the thin monocrystalline silicon substrate 101 is joined onto the silicon substrate 110 through the $SiO_2$ film 111, and in the monocrystalline silicon substrate 101, the cantilever 102 is formed which has the weight 139 at the tip thereof. Further, in one surface of the weight 139 (the bottom surface in Fig. 1), the $n^+$ type diffusion layer 117 is formed, while in the bottom surface of the monocrystalline

silicon substrate 101 facing the surface of the weight, the $n^+$ type polysilicon 122 (oscillation electrode 114) is formed so that the $n^+$ type diffusion layer 117 and the $n^+$ type polysilicon 122 form oscillation electrodes. By applying an AC power to these oscillation electrodes, static electricity is created which oscillates the weight 139. In addition, in the axial direction which is perpendicular to the direction of the oscillation of the weight 139, the $n^+$ type diffusion layer 117 is formed in one surface of the weight 139, while the $n^+$ type diffusion layer 117 is formed in a wall surface of the monocrystalline silicon substrate 101 facing the surface of the weight so that the $n^+$ type diffusion layer 117 of the weight 139 side and the $n^+$ type diffusion layer 117 on the side of the wall surface of the monocrystalline silicon substrate 101 form a detecting electrode for detecting a yaw rate. The yaw rate detecting electrode detects a change in the electrical capacitance and hence a yaw rate which acts in the same direction is detected.

[0026]

That is, an AC power is applied to the oscillation electrodes (i.e., the $n^+$ type diffusion layer 117 and the $n^+$ type polysilicon 122) to oscillate the weight 139 by static electricity. Under this condition, the yaw rate detecting electrode (i.e., the $n^+$ type diffusion layer 117 of the weight 139 side and the $n^+$ type diffusion layer 117 on the side of the wall surface of the monocrystalline silicon substrate 101), detects a change in an electrical capacitance in the axial direction which is perpendicular to the direction of the oscillation of the weight 139, whereby a yaw rate which acts in the same direction is detected.

[0027]

Thus, in this embodiment, the recess portion 115 and the trench 116 are formed as a groove of a predetermined depth in the major surface of the monocrystalline silicon substrate 101 to thereby form the cantilever 102 which has the weight 139 (first step). In inner walls of the recess portion 115 and

the trench 116 which surround a substrate surface region which serves as the weight 139 and the weight 139, the $n^+$ type diffusion layers 117 which serve as a pair of electrodes are formed facing each other on the opposite sides of the trench 116 in the direction of the surface of the substrate (a left-to-right direction in Fig. 4). At the same time, in a substrate surface region which will serve as the weight 139, in the direction which is perpendicular to the direction of the surface of the substrate (up-to-down direction of Fig. 5; the direction of the thickness of the silicon substrate 101), the $n^+$ type diffusion layer 117 (first electrode) is formed (second step). Next, the recess portion 115 and the trench 116 are filled with a filling material, i.e., the polysilicon film 119, and the $n^+$ type polysilicon film 122 (electrode) is formed on the opposite sides of the polysilicon film 119 so as to face the $n^+$ type diffusion layer 117 (first electrode), followed by smoothing the major surface of the monocrystalline silicon substrate 101 (third step). The major surface of the monocrystalline silicon substrate 101 and the silicon substrate 110 are then joined to each other (fourth step). Thereafter, the back surface side of the monocrystalline silicon substrate 101 is then polished by a predetermined amount to thereby make the monocrystalline silicon substrate 101 thin (fifth step). The polysilicon film 119 is then etched from the back surface side of the monocrystalline silicon substrate 101, whereby the cantilever 102 which has the weight 139 is formed (sixth step).

[0028]

As a result, the semiconductor mechanical sensor comprises the thin monocrystalline silicon substrate 101 which is joined onto the silicon substrate 110 through the $SiO_2$ film 111 (insulation film), the cantilever 102 which is formed in the monocrystalline silicon substrate 101 and which has the weight 139, the movable electrode 112 and the oscillation electrode 114 which are formed in one surface of the

weight 139 and a wall surface which corresponds to the weight surface (first electrodes), and the projections 103 to 105 and the fixed electrodes 133 to 138 which are formed in one surface of the weight 139 and a wall surface which faces the weight surface in the axial direction which is perpendicular to the movable electrode 112 of the weight 139 and the oscillation electrode 114 (second electrodes).

[0029]

Either one of the electrodes, namely, the movable electrode 112 or the oscillation electrode 114 is formed in parallel to the major surface of the monocrystalline silicon substrate 101.

Further, all electrode contacting portions are formed on the same surface of the thin monocrystalline silicon substrate 101.

[0030]

Thus, the semiconductor yaw rate sensor comprises the thin monocrystalline silicon substrate 101 joined to the silicon substrate 110 through the $SiO_2$ film 111, the cantilever 102 which is formed in the monocrystalline silicon substrate 101 and which has the weight 139 at the tip, the oscillation electrodes which are formed in one surface of the weight 139 and a wall surface of the monocrystalline silicon substrate 101 facing the weight surface, the oscillation electrodes oscillating the weight 139 by static electricity when an AC power is applied thereto, and the yaw rate detecting electrode which is formed in one surface of the weight 139 and a wall surface of the monocrystalline silicon substrate 101 facing the weight surface in the axial direction which is perpendicular to the direction of oscillation of the weight 139, the yaw rate detecting electrode detecting a change in an electrical capacitance and hence a yaw rate which acts in the same direction.

[0031]

In this manner, processes are performed stably and a device which is stable and accurate is manufactured without

contamination by using a surface micro machining technique, without performing a thermal treatment and a photolithographic process during a wafer forming process, especially during fabrication of an IC circuit, in a condition where a wafer recess portion, a through hole and the like have been already formed.

[0032]

Although the foregoing has described the present embodiment in relation to the case where the oscillation electrode and the sense electrode are buried in the substrate, the sense electrode may be omitted to reduce cost, in which case, the silicon substrate as it is may be used as the oscillation electrode, unlike the structure described above.

[0033]

In addition, although the electrodes which are formed in parallel to the wafer surface are used as the sense electrode and the oscillation electrode and the electrodes which are disposed in the vertical direction are used as the fixed electrodes for detecting the Corioli's force, in the present embodiment, the opposite is also possible. That is, one of the fixed electrodes which are disposed in the vertical direction in the silicon substrate 101 may be used as the oscillation electrode, and the other one of the fixed electrodes may be used as the sense electrode for performing feedback, while the electrodes which are formed in parallel to the wafer surface may be used as electrodes for detecting the Corioli's force.

[0034]

Further, as the polysilicon film 119 for filling the recess portion 115 and the trench 116 (i.e., a polycrystalline silicon film), an amorphous silicon film or a silicon film in which a polycrystalline portion and an amorphous portion are mixed may be used.

(Second Embodiment)

Next, a second embodiment of the present invention will be explained mainly emphasizing the difference from the first

embodiment.

[0035]

This embodiment is intended to further increase output as compared with the first embodiment and to prevent destruction of the beam by excessive shock and the like.

Figs. 9 to 15 show steps for manufacturing the sensor. In the following, the manufacturing steps will be described.

[0036]

In Fig. 4 of the first embodiment, as shown in Fig. 9, an $Si_3N_4$ film 125 having a thickness of 200 to 2000Å is formed by the LPCVD method after formation of the $SiO_2$ film 118. In this embodiment, the thickness of the $Si_3N_4$ film 125 is 500Å.

[0037]

In processes similar to those of the first embodiment, polishing and flattening of the surface as shown in Fig. 7 in relation to the first embodiment are performed.

Following this, a resist 126 of Fig. 9 is patterned to a predetermined pattern by a photolithographic technique, and a region which will serve as the sensor part of the monocrystalline silicon substrate 101 is removed by dry etching or other suitable method as shown in Fig. 10.

[0038]

Next, using the resist 126 as a mask, the $SiO_2$ film 118 is removed by wet etching, for example, which primarily uses hydrofluoric acid as an etchant, followed by removal of the resist 126.

[0039]

In the following, for clarity of explanation, an enlarged view of a portion of the sensor part B of Fig. 10 will be referred to.

Fig. 11 shows the enlarged portion.

[0040]

As shown in Fig. 12, using the $Si_3N_4$ film 125 as a mask, an $SiO_2$ film 127 is grown to a thickness of 500 to 10000Å by thermal oxidization. In this embodiment, the thickness of the $SiO_2$ film 127 is 1000Å.

[0041]

Next, as shown in Fig. 13, the $Si_3N_4$ film 125 used as a mask during thermal oxidization is removed by plasma etching or etching using heated phosphoric acid. A polysilicon 128 is then grown by the LPCVD method or other suitable method, on the surface. The surface of the polysilicon 128 is then selectively polished and removed using the $SiO_2$ film 127 as a stopper.

[0042]

Further, the surface is treated with a TMAH (tetramethylammoniumhidroxide) solution. At this stage, in a peripheral portion, an IC circuit and the like are formed (not shown).

[0043]

Thereafter, as shown in Fig. 14, an $Si_3N_4$ film 129 having a thickness of 500 to 2000Å is formed on the surface, and an $n^+$ type polysilicon layer 130 is formed which will serve as a stopper against excessive vibration of the electrode layer and the sensor. Following this, a BPSG film 131 is formed as a surface protection film. This film may be formed by an $Si_3N_4$ film or the like. A window portion 132 is then formed.

[0044]

Then, as shown in Fig. 15, the polysilicon 119 and the polysilicon 128 are etched through the window portion 132 with the TMAH solution.

In this manner, a sensor which comprises a movable portion (cantilever) which is entirely surrounded by an electrode and a stopper is obtained. In such a structure, when the weight portion is oscillated in a direction which is perpendicular to the substrate, as shown in Fig. 15, since $a > b$ and b is within the range of a, there will be almost no capacitance change created during detection of a yaw rate due to oscillation. Such relation $a > b$ is attainable in the first embodiment as well.

[0045]

Fig. 16 is a view which clearly shows more detail of the

overall structure.

As described above, in the present embodiment, since the stopper member is disposed above the cantilever 102, output is further increased, as compared with the first embodiment, and destruction of the cantilever 102 by excessive shock and the like is prevented.

[0046]

It is to be noted that the present invention is not limited to the embodiments described above. For example, two pairs of the sensor units may be arranged in directions perpendicular to each other in order to detect yaw rates in the two axial directions. Further, the present invention is not limited to a cantilever. The present invention is also not limited to detection of a yaw rate. For instance, the oscillation electrode of the embodiments described above may be replaced with an electrode which detects a capacitance derived from displacement in an up-to-down direction so that the present invention is applied to a mechanical sensor which is capable of detecting displacements in two directions.

[0047]

[Effect of the Invention]

As heretofore described in detail, according to the present invention, it is possible to create effects by which a yaw rate sensor using a beam oscillation type capacitance detection system and a method of manufacturing the same can be easily obtained, and a semiconductor mechanical sensor which can detect movement conditions in two or three directions and a method of manufacturing the same can also be obtained.

[BRIEF EXPLANATION OF THE DRAWINGS]

[Fig. 1]

is a cross-sectional view of a semiconductor yaw rate sensor according to the first embodiment.

[Fig. 2]

is a schematic plan view of a semiconductor yaw rate sensor according to the first embodiment.

[Fig. 3]

is a plan view of a semiconductor yaw rate sensor including electrodes.

[Fig. 4]

is a cross-sectional view showing manufacturing steps.

[Fig. 5]

is a cross-sectional view showing manufacturing steps.

[Fig. 6]

is a cross-sectional view showing manufacturing steps.

[Fig. 7]

is a cross-sectional view showing manufacturing steps.

[Fig. 8]

is a cross-sectional view showing manufacturing steps.

[Fig. 9]

is a cross-sectional view showing manufacturing steps of a semiconductor yaw rate sensor according to the second embodiment.

[Fig. 10]

is a cross-sectional view showing manufacturing steps.

[Fig. 11]

is a cross-sectional view showing manufacturing steps.

[Fig. 12]

is a cross-sectional view showing manufacturing steps.

[Fig. 13]

is a cross-sectional view showing manufacturing steps.

[Fig. 14]

is a cross-sectional view showing manufacturing steps.

[Fig. 15]

is a cross-sectional view showing manufacturing steps.

[Fig. 16]

is a cross-sectional view showing manufacturing steps.

[Fig. 17]

is a explanatory view for explaining the principle of a sensor.

[Explanation of Reference Numerals]

101 ... monocrystalline silicon substrate

102 ... cantilever

103 - 105 ... projections constituting second electrodes
110 ... silicon substrate
111 ... $SiO_2$ film as an insulation film
112 ... movable electrode of first electrodes
114 ... oscillation electrode of first electrodes
115 ... recess portion constituting a groove
116 ... trench constituting a groove
117 ... $n^+$ type diffusion layer
119 ... polysilicon film as a filling material
122 ... $n^+$ type polysilicon film
133 - 138 ... fixed electrodes constituting second electrodes
139 ... weight

[DOCUMENT NAME] ABSTRACT

[ABSTRACT]

[OBJECT] A yaw rate sensor using a beam oscillation type capacitance detection system and a method of manufacturing the same are easily provided, and a semiconductor mechanical sensor which can detect movement conditions in two or three directions and a method of manufacturing the same are also provided.

[CONSTITUTION] A recess portion and a trench are formed in a major surface of a monocrystalline silicon substrate 101, a $n^+$ type diffusion layer 117 is formed as a pair of electrodes facing each other on the opposite sides of the trench in a direction of the surface of the substrate, and at the same time, a $n^+$ type diffusion layer 117 is formed in a direction which is perpendicular to the direction of the surface of the substrate. Then, the recess portion and the trench are filled with a polysilicon film and the $n^+$ type polysilicon film is formed on the opposite sides of the polysilicon film, followed by smoothing the major surface of the substrate 101, and the major surface of the substrate 101 and a silicon substrate 110 are joined. Further, a back surface of the substrate 101 is polished by a predetermined amount to thereby make the substrate 101 thin and the polysilicon film is etched from the back surface side of the substrate 101, whereby the cantilever having a weight 139 is formed.

[REPRESENTATIVE DRAWING] Fig. 1